Preweaning performance and body composition of calves from straightbred Nellore and *Bos taurus* × Nellore crosses[1]

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ABSTRACT: The objectives were to evaluate preweaning performance, body composition, and efficiency of calves representing straightbred Nellore (NL), F_1, and 3-breed-cross systems. Energy requirements, milk production, and efficiency of 39 cow-calf pairs were recorded from straightbred NL calves from NL cows (10), crossbred (Angus-sired) calves from NL cows (ANL: 9), and crossbred calves (CC; Canchim-sired: 5/8 Charolais, 3/8 Zebu) from ANL (10) and Simmental × NL (10) cows. Cows and their respective calves were individually fed from birth to weaning (17 to 190 d postpartum). At 38 d of age, corn silage (7.8% CP, 2.19 Mcal of ME/kg of DM) was available to calves ad libitum. Milk production at 42, 98, 126, and 180 d postpartum was recorded by weighing calves before and after suckling. The ratio between GE and ME of milk was considered 1:0.93. Calves were slaughtered at weaning and the 9th-, 10th-, and 11th-rib section was removed for body composition estimation. The ANL calves were lighter ($P < 0.01$) at birth than the CC calves; the NL calves were intermediate. At weaning, the CC calves were heavier ($P = 0.04$) than the NL and ANL calves (230 ± 5.5 vs. 172 ± 8.1 and 209 ± 8.6 kg, respectively). The ANL calves had greater (371 ± 27 Mcal; $P = 0.01$) silage intake than the NL (270 ± 25 Mcal) and CC (279 ± 17 Mcal) calves. Milk energy intake was greater for the CC calves (970 ± 38 Mcal of ME; $P = 0.005$) than the NL (670 ± 57 Mcal of ME) and ANL (743 ± 61 Mcal of ME) calves. The ANL calves compensated for the reduced milk production of the NL cows, which supplied less of their energy requirement for growth by increased silage intake. Calves from crossbred cows received a greater proportion of their total energy intake from milk. Crossbred calves had greater ($P < 0.03$) retained energy (retained energy = weaning body energy − birth body energy) than the NL calves (388 ± 23 for ANL, and 438 ± 15 for CC vs. 312 ± 22 Mcal for NL calves). Percentages of water ($P = 0.74$) and chemical fat ($P = 0.51$) were similar among groups (63.7 ± 0.6 and 14.3 ± 0.7% for ANL calves, 63.1 ± 0.4 and 14.7 ± 0.5% for CC calves, and 63.3 ± 0.6 and 13.7 ± 0.7% of empty BW for water and chemical fat, respectively, for NL calves). Energetic efficiency (kcal of retained energy/Mcal of ME intake) was similar ($P = 0.52$) among groups (358 ± 22 for ANL calves, 355 ± 14 for CC calves, and 327 ± 22 for NL calves). The greater BW gains and the differences in empty body composition at weaning were not enough to compensate for the greater ME intake of crossbreds. In this study, the crossbreeding systems evaluated increased preweaning calf performance but did not affect gross or energetic calf efficiency.

Key words: average daily gain, crossbreeding, energy requirement, retained energy, weaning weight

INTRODUCTION

Efficiency of beef production depends on the many traits expressed in the breeding herd and in growing and finishing animals (Archer et al., 1999). Brelin and Brannang (1982) reported strong genetic correlations between growth rate and feed conversion ratio. However, some authors recorded disadvantageous genetic correlations between BW and age at first calving (Mariante, 1978; Silva et al., 2000) and mature BW (Lôbo et

al., 2000; Silva et al., 2000). Thus, greater feed requirements for the cow herd would be expected. Because feed is a major cost in beef production, improvement of the output of beef per unit of feed used over the whole production system could have significant economic and environmental benefits. Dickerson (1970) suggested that the greatest genetic opportunity for reducing costs is to increase total product value per female with a minimal increase in body size. Crossbreeding programs can be an option to improve the ratio between inputs and outputs of beef production. Notter et al. (1979) showed that systems that used individual heterosis were more efficient than straight breeding systems, and systems that used individual and maternal heterosis were more efficient than those using only individual heterosis.

Beef production in Brazil has been attained mainly in extensive systems on pasture, and *Bos indicus* breeds constitute approximately 80% of the beef cattle herd. Differences in additive genetic merit of *Bos taurus* and *B. indicus* can be used to enhance the production level, exploiting heterosis and complementarity effects of crossbreds. The objectives of this study were to evaluate preweaning performance, body composition, and efficiency of calves representing 3 mating systems, straightbred Nellore (**NL**) calves from NL cows, crossbred calves (Angus-sired) from NL cows (**ANL**), and crossbred calves from crossbred cows [Canchim-sired calves from ANL and Simmental × NL cows (**SNL**)].

MATERIALS AND METHODS

All procedures with animals were conducted according to the University of São Paulo ethical standards established by the College of Agriculture Research Commission.

Animals and Management

The study was conducted at the Embrapa Research Station (São Carlos, São Paulo, Brazil). The preweaning phase was evaluated from January to October of 2006. Nellore and ANL or SNL cows, produced from the same NL breeding herd, were sampled for use in the study. Twenty crossbred cows (10 ANL and 10 SNL) were artificially inseminated with Canchim (5/8 Charolais, 3/8 Zebu) bulls, whereas 20 NL females were mated by AI to NL or Aberdeen Angus bulls during the fall breeding season from April to June of 2005. At the beginning of the experiment, cows were 60 ± 1.3 mo of age and with their third calf. Individual BW change and ME intake (**MEI**) of dams were recorded from 189 ± 11 to 263 ± 12 d after mating. Cows were transferred to pasture for calving. During this period, they received a mineralized salt. At 17 ± 8.9 d postpartum, 39 cow-calf pairs were redistributed in the individual pens. There were 5 male and 5 female calves in each group: 1/2 Canchim, 1/4 Simmental, 1/4 NL (**CSN**) and 1/2 Canchim, 1/4 Angus, 1/4 NL (**CAN**), 8 males and 2 females in the NL group, and 4 males and 5

females in the ANL group (1/2 Angus, 1/2 NL). One ANL calf was born dead. None of the male calves was castrated or implanted. The results are presented for mating system: straightbred (NL; n = 10), crossbred calves from NL cows (ANL; n = 9) and crossbred calves from crossbred cows (**CC**: CAN and CSN; n = 20). The mating system represents the effect *B. taurus* percentage (0, 50, and 56.3% *B. taurus*, respectively) has on preweaning performance.

Cows were fed a total mixed diet during the pregnancy and lactation trials. The cow energy requirements and cow-calf efficiency were presented in a separate manuscript (Calegare et al., 2009). Beginning at 38 d of age, corn silage (2.19 Mcal of ME and 7.8% CP, on a DM basis) was provided to calves ad libitum. Silage ME content was estimated according to the equation of Weiss et al. (1992). The DM of feed was determined weekly and the orts were collected, weighed, sampled for DM analysis, and discarded daily. Cow and calf feeders were separated physically so that cows had no access to the feeders of the calves and vice versa, and individual cow and calf intakes could be recorded. Animals were fed twice daily at 0700 and 1500 h. Cows and calves were weighed, in the morning before feeding, at 14-d intervals. Milk yields at 42, 98, 126, and 180 d postpartum were measured by using the weigh-suckle-weigh technique (Cundiff et al., 1974). Before each morning sampling, cow-calf pairs were separated for 16 h. Calves were then weighed, allowed to suckle under constant observation, and then reweighed. This was repeated after the pairs were separated for another 8 h. The daily milk yield was determined by adding the 16- and 8-h weight changes. At 60 and 150 d postpartum, calves were removed for the same 16- and 8-h intervals, and each cow was milked by hand. Samples of each milking were combined for analysis. Total milk solids were determined and milk samples were analyzed for fat, protein, and lactose by infrared spectrophotometry (Bentley Instruments Inc., Chaska, MN). To aid in milking, 2 mL of oxytocin (Ocitocina Forte UCB, Jaboticabal, São Paulo, Brazil) per cow per milking was administered i.v. Total milk yields at 190 d of lactation and at peak lactation were calculated by using the equations developed by Jenkins and Ferrell (1984). Secreted milk energy was estimated by using values of 9.29, 5.47, and 3.95 Mcal/kg for fat, protein, and lactose, respectively (NRC, 2001). Milk MEI for the calves was calculated by using the relationship 1:0.93 between GE (milk energy secreted) and ME (NRC, 2001). Calf MEI from silage and from milk for 190 d preweaning was recorded individually.

Experimental Slaughter

Calves were slaughtered at weaning (190 ± 11 d of age). The HCW, liver, kidneys, heart, and kidney-pelvic fat weights were recorded. After a 24-h chill, the right and left sides of the carcass were weighed (chilled carcass weight) and the left side was separated. The

LM area and 12th-rib fat thickness were measured and the 9th-, 10th-, and 11th-rib section was removed according to Hankins and Howe (1946) for body composition estimation. Body composition at birth was considered as 77.5% water, 4.0% fat, 14.7% protein, and 3.5% ash in the BW for all groups (Haigh et al., 1920). The original methodology of Hankins and Howe (1946) was modified, and whole-rib sections (bones and soft tissue) were ground through a homogenizer (P-33A-3-789, 15 horsepower Hermann, Nova Odessa, São Paulo, Brazil) and samples were freeze-dried. Water content of each rib section was calculated from the weight before and after drying.

Calf empty BW (**EBW**) was estimated from HCW based on the following equation (Henrique et al., 2003):

$$EBW \ (kg) = 1.6093 \times HCW \ (kg) + 0.6784 \ (r = 0.99).$$

Water percentage and chemical fat percentage of EBW were estimated from equations established by linear regressions of percentages of water and chemical fat in the empty body on water in the 9th-, 10th-, and 11th-rib section. The equations used for NL calves (Eq. 1 and 2) were developed for NL bulls by Lanna et al. (1995) and the equations used for ANL, CAN (Eq. 3 and 4), and CSN calves (Eq. 5 and 6) were developed by A. Berndt (Instituto de Zootecnia, Nova Odessa, São Paulo, Brazil), M. M. Alencar, G. M. Cruz (EMBRAPA, São Carlos, São Paulo, Brazil), and D. P. D. Lanna (unpublished data) for similar *B. taurus* × *B. indicus* crosses:

$$\text{\% Water, EBW} = 0.6806 \times \text{\% Water (rib section)} + 22.998 \ (r = 0.91), \quad [1]$$

$$\text{\% Chemical Fat, EBW} = -0.7968 \times \text{\% Water (rib section)} + 60.815 \ (r = 0.91), \quad [2]$$

$$\text{\% Water, EBW} = 0.5516 \times \text{\% Water (rib section)} + 30.347 \ (r = 0.89), \quad [3]$$

$$\text{\% Chemical Fat, EBW} = -0.661 \times \text{\% Water (rib section)} + 54.273 \ (r = 0.83), \quad [4]$$

$$\text{\% Water, EBW} = 0.5757 \times \text{\% Water (rib section)} + 28.499 \ (r = 0.88), \quad [5]$$

$$\text{\% Chemical Fat, EBW} = -0.7155 \times \text{\% Water (rib section)} + 57.386 \ (r = 0.85). \quad [6]$$

Protein and ash in the empty body were calculated from the estimated fat and water by using the ratio 80:20 between protein and ash in the fat-free DM (Reid et al., 1955; Boin et al., 1994). The energy concentra-

tion used for protein and fat was 5.539 and 9.385 Mcal/kg of EBW (Garrett and Hinman, 1969), respectively. Retained energy (**RE**) was calculated as the difference between empty body energy at weaning and body energy at birth. Calf efficiency was calculated as gross efficiency (grams of calf BW gain/total MEI, milk plus silage) and the energetic efficiency, defined as RE/total MEI by calf, was calculated during preweaning.

Statistical Analyses

Analyses of variance were performed with the GLM procedure (PROC GLM; SAS Inst. Inc., Cary, NC) including mating system and sex of calf as fixed effects. The interaction between them also was tested and, when not significant, was deleted from the model. Weaning age was included as a covariate to evaluate all variables, excluding birth weight and birth energy. The Tukey test was used to compare mating system means. The effect of increasing percentage of *B. taurus* (0, 50, and 56.3%) in the mating systems was evaluated by linear and quadratic contrasts (PROC GLM). Contrast of breed type was used to compare the calf means between CAN and CSN calves.

RESULTS AND DISCUSSION

Preweaning Growth Performance

A quadratic effect ($P = 0.002$) was detected for birth weight (Table 1); ANL calves were lighter ($P = 0.001$) at birth than CC calves. At weaning, CC calves were heavier ($P = 0.04$) than ANL and NL calves: 230 ± 5.5 vs. 209 ± 8.6 for ANL and 172 ± 8.1 kg for NL calves (Table 1). The CAN and CSN calves are represented by the latest 2 crosses. The other calf group studied by Calegare et al. (2007) was a Canchim-sired calf from Canchim × NL dam. The authors observed that both CAN and CSN had 34% greater total preweaning BW gain than NL calves, whereas Canchim-sired calves from Canchim × NL dams had 22% greater gain than NL calves. Several studies (Damon et al., 1959; Reynolds et al., 1978; Browning et al., 1995) have also reported greater preweaning performance of crossbred calves compared with straightbreds. In this study, ANL calves gained 211 g more daily and weighed 37 kg more at weaning than NL calves (Table 1). Reynolds et al. (1982) reported that reciprocal Brahman × Angus crossbred calves had 25% (161 g) greater daily BW gain and were 23% (36.6 kg) heavier at 205 d of age than the straightbred Angus and Brahman calves. Gregory et al. (1965) and Pahnish et al. (1969) showed that crossbred calves gained faster than straightbred calves from birth to weaning, resulting in an increase of approximately 5% in weaning weight because of heterosis. The ANL and CC calves had approximately 30 and 41% greater ADG than straightbred NL from birth to weaning. Cundiff et al. (1992) observed that the cumulative preweaning gain of 3-way-cross calves was approxi-

Table 1. Least squares means (±SE) of preweaning performance, energy intake, and efficiency of calves for 3 mating systems (straightbred Nellore, F_1, and 3-breed cross)

Variable	Contrast		Mating system[1]			
	Linear	Quadratic	NL	ANL	CC	P-value
Birth wt, kg	NS	0.002	36.3 ± 2.2[ab]	33.3 ± 1.8[b]	41.3 ± 1.2[a]	0.001
Weaning wt, kg (190 d)	<0.0001	NS	172 ± 8.1[c]	209 ± 8.6[b]	230 ± 5.5[a]	0.04
BW gain, kg	<0.0001	NS	134 ± 7.4[b]	175 ± 7.8[a]	189 ± 5.0[a]	<0.01
BW gain, g/d	<0.0001	NS	706 ± 39[b]	917 ± 41[a]	993 ± 24[a]	0.001
Milk intake, Mcal of ME	0.005	NS	670 ± 57[b]	743 ± 61[b]	970 ± 38[a]	0.005
Silage intake, Mcal of ME	NS	0.006	270 ± 25[b]	371 ± 27[a]	279 ± 17[b]	0.01
Total ME intake, Mcal	0.0004	NS	940 ± 54[c]	1,114 ± 57[b]	1,249 ± 36[a]	0.05
Body energy at birth,[2] Mcal	NS	0.002	43.1 ± 2.6[ab]	39.6 ± 2.2[b]	49.1 ± 1.5[a]	0.001
Body energy at weaning, Mcal	0.0003	NS	355 ± 23[c]	429 ± 23[b]	487 ± 15[a]	0.04
Retained energy, Mcal	0.0003	NS	312 ± 22[b]	388 ± 23[ab]	438 ± 15[a]	0.03
Gross efficiency,[3] g/Mcal	NS	NS	143 ± 8.2	161 ± 8.9	153 ± 5.7	0.39
Energetic efficiency,[4] kcal/Mcal	NS	NS	327 ± 22	358 ± 22	355 ± 14	0.52

[a-c]Means within a row without a common superscript letter differ ($P < 0.05$); NS = not significant.
[1]Straightbred Nellore (NL; n = 10); 1/2 Angus, 1/2 Nellore (ANL; n = 9); 1/2 Canchim, 1/4 Angus, 1/4 Nellore (CC; n = 20).
[2]Calculated based on the data of Haigh et al. (1920).
[3]Grams of BW gain/Mcal of ME intake (milk plus silage).
[4]Kilocalories of retained energy/Mcal of ME intake (milk plus silage).

mately 36% greater than that of straightbred calves. Prayaga (2003) observed that all purebreds evaluated had slower preweaning ADG than the overall mean (832 g/d), and calves reared by Zebu crossbred dams in F_1 backcrosses (861 g/d) and 3-breed crosses (885 g/d) performed well for preweaning growth traits. Roso and Fries (1998) observed the greatest values of total heterosis (maternal and individual heterosis) when crossbred dams were used. Progeny weaning weight could be affected by nutritional environment, age at weaning, genetic potential for growth, milk production of dams, and the interactions among these factors (Jenkins et al., 1991). The crossbreeding programs can increase the production potential if the appropriate combination of breed and environment is established.

Nellore and ANL calves had less ($P = 0.005$) MEI from milk than CC calves, whereas crossbred cows (ANL, SNL) had greater milk production than NL dams. The milk production results are presented in a separate manuscript on cow-calf efficiency (Calegare et al., 2009). Total calf MEI and MEI from milk followed a linear effect, whereas MEI from silage had a quadratic effect (Table 1). The ANL calves had greater silage intake ($P = 0.01$) than the NL and CC groups. Milk production from NL cows was probably insufficient to support the requirements for growth of an ANL calf. Abdelsamei et al. (2005) evaluated calf preweaning performance using 5 amounts of reconstituted milk and reported that a linear increase in milk DMI was associated with a decrease in alfalfa hay intake. Lusby et al. (1976) reported that Holstein progeny consumed the most milk and the least forage, whereas the opposite was recorded for Hereford progeny evaluated in feedlot facilities or on pasture from calving to weaning at 240 d of age. Calves fed small amounts of milk consumed more forage to compensate for the reduced nutrient

supply from milk (Church et al., 1980). Silage intake of NL calves was less than silage intake of ANL calves, even though milk intake was similar; this could imply that NL calves have less appetite and potentially less growth and reduced maintenance requirements compared with crossbreds.

There was an interaction between sex and mating system ($P = 0.003$) for birth weight. The ANL males were lighter than females, 29.9 ± 2.7 vs. 36.7 ± 2.4 kg, whereas the CC males were heavier than females, 43.9 ± 1.7 vs. 38.7 ± 1.7 kg. Browning et al. (1995) evaluated calves born to Angus, Brahman, or Tuli bulls and Brahman dams; within sire breeds, a sex difference was detected only in Brahman-sired calves. Ellis et al. (1965) reported that male calves from Brahman dams and sired by Hereford bulls were approximately 3 kg lighter than female calves, whereas the opposite was observed in Brahman bulls mated to Hereford dams. Riley et al. (2007) observed that Angus-sired female calves from Brahman dams were heavier than male calves at birth.

Body Composition at Weaning

Taking into account that the EBW is the most important variable affecting body composition (Fortin et al., 1980), we observed that ANL and CC calves had greater empty body energy at weaning ($P = 0.04$) and greater RE ($P = 0.03$) than NL calves (Table 1). The CC calves had greater ($P = 0.04$) EBW and HCW than the NL and ANL calves (Table 2). The ANL calves had a greater percentage of liver in HCW ($P = 0.05$) than the CC calves. Both ANL and CC calves had greater liver ($P < 0.01$) and kidney ($P = 0.003$) weights than NL calves. The LM area was proportional with EBW and HCW (Table 2) and was greater ($P < 0.01$)

Table 2. Least squares means (±SE) of calf body composition at weaning (190 ± 11 d) for 3 mating systems (straightbred Nellore, F_1, and 3-breed cross)

Variable	Contrast		Mating system[1]			
	Linear	Quadratic	NL	ANL	CC	P-value
Empty BW (EBW), kg	<0.0001	NS	151 ± 8.0[c]	185 ± 8.2[b]	207 ± 5.2[a]	0.04
HCW, kg	<0.0001	NS	93 ± 5.0[c]	115 ± 5.0[b]	128 ± 3.0[a]	0.04
Dressing percent	NS	NS	55.0 ± 0.5	54.7 ± 0.5	55.6 ± 0.3	0.18
Liver, kg	<0.0001	NS	1.77 ± 0.09[b]	2.26 ± 0.09[a]	2.34 ± 0.06[a]	<0.01
Kidney, kg	0.0003	NS	0.36 ± 0.03[b]	0.48 ± 0.03[a]	0.50 ± 0.02[a]	0.003
Heart, kg	<0.0001	NS	0.60 ± 0.04[c]	0.77 ± 0.04[b]	0.86 ± 0.02[a]	0.06
Kidney-pelvic fat, kg	0.054	NS	3.38 ± 0.72[b]	4.94 ± 0.72[ab]	5.10 ± 0.48[a]	0.05
Liver, % of HCW	NS	0.041	1.90 ± 0.06[ab]	1.98 ± 0.06[a]	1.84 ± 0.04[b]	0.05
Kidney, % of HCW	NS	NS	0.39 ± 0.02	0.42 ± 0.02	0.39 ± 0.01	0.38
Heart, % of HCW	NS	NS	0.65 ± 0.02	0.68 ± 0.02	0.67 ± 0.01	0.92
Kidney-pelvic fat, % of HCW	NS	NS	3.47 ± 0.59	4.29 ± 0.59	4.04 ± 0.38	0.65
LM area, cm^2	<0.0001	NS	37.7 ± 2.3[c]	47.9 ± 1.9[b]	51.6 ± 1.2[a]	<0.01
12th-rib fat thickness, mm	NS	NS	1.6 ± 0.6	2.4 ± 0.5	2.2 ± 0.3	0.58
Water, % of rib cut	NS	NS	59.0 ± 1.0	60.4 ± 1.0	59.8 ± 0.7	0.66
Water, % of EBW	NS	NS	63.3 ± 0.6	63.7 ± 0.6	63.1 ± 0.4	0.74
Chemical fat, % of EBW	NS	NS	13.7 ± 0.7	14.3 ± 0.7	14.7 ± 0.5	0.51
Protein, % of EBW	<0.0001	NS	18.4 ± 0.09[a]	17.6 ± 0.09[b]	17.1 ± 0.06[b]	<0.001
Ash, % of EBW	<0.0001	NS	4.61 ± 0.03[a]	4.41 ± 0.03[b]	4.44 ± 0.02[b]	<0.001

[a-c]Means within a row without a common superscript letter differ ($P < 0.05$); NS = not significant.

[1]Straightbred Nellore (NL; n = 10); 1/2 Angus, 1/2 Nellore (ANL; n = 9); 1/2 Canchim, 1/4 Angus, 1/4 Nellore, 1/2 Canchim, 1/4 Simmental, 1/4 Nellore (CC; n = 20).

for CC than for NL and ANL calves. The 12th-rib fat thickness was not different ($P = 0.58$) among groups. Within mating system, there was a sex difference only in 3-breed-cross calves for LM area ($P = 0.04$) and 12th-rib fat thickness ($P = 0.02$); males had greater LM area and less 12th-rib fat thickness than CC female calves ($54.2 ± 1.7$ cm^2 and $1.3 ± 0.5$ mm vs. $49.0 ± 1.7$ cm^2 and $3.1 ± 0.5$ mm). The NL calves had greater percentages of protein ($P < 0.001$) and ash ($P < 0.001$) in EBW than ANL and CC calves; water ($P = 0.74$) and chemical fat ($P = 0.51$) were not different among groups (Table 2).

Reynolds et al. (1982) evaluated Brahman- and Angus-sired calves and reported a greater deposition of fat and less deposition of muscle tissue and bone in the Angus-sired calves. The CAN calves had 7.8% greater chemical fat deposition ($P = 0.28$) and a smaller ($P < 0.001$) percentage of protein in EBW than CSN calves: $15.2 ± 0.7$ vs. $14.1 ± 0.7\%$ of fat and $17.5 ± 0.1$ vs. $18.1 ± 0.1\%$ of protein, respectively. Calegare et al. (2007) reported a smaller water percentage ($61.5 ± 0.7$ vs. $64.8 ± 0.8\%$ of EBW) and greater chemical fat percentage ($13.7 ± 0.8$ vs. $10.8 ± 0.8\%$ of EBW) for CAN than for CSN calves at weaning. Historically, British breeds such as Angus have tended to be smaller and fatter than Continental breeds (e.g., Simmental) at the same age. Depending on the production system and beef market demand, specific breed types could be more or less advantageous. Buckley et al. (1990) reported decreased water percentage and greater fat percentage in EBW for Hereford heifers compared with Simmental and Charolais at 7 mo. Charolais and Simmental crosses grew faster and had leaner carcasses than Hereford × Angus crosses (Koch et al., 1976).

Independent of breed type, sex influenced water ($P < 0.01$), chemical fat ($P < 0.01$), protein ($P = 0.03$), and ash ($P = 0.03$) percentages of EBW (Table 3). Fortin et al. (1980) reported that heifers deposited water at a reduced rate compared with steers and bulls, and the protein deposition was faster in bulls than in steers and heifers. In this study, feed efficiency was not different between sexes (Table 3), even though one might have expected bull calves to be more efficient than heifers, which deposited less protein from birth to weaning.

Gross and Energetic Efficiency

A difference in gross efficiency was not detected ($P = 0.39$) among the 3 groups of calves. The greater BW gain of crossbred calves corresponded to the greater MEI preweaning. Nellore calves had a reduced growth rate and less MEI, thus were not less efficient in the conversion of feed to BW gain. Almeida et al. (2005) analyzed feed intake, daily gain, and feed efficiency data from NL and crossbred males in Brazilian commercial feedlots and they reported a similar feed efficiency between breed types.

Nellore, ANL, and CC calves had similar ($P = 0.52$) energetic efficiency. Calegare et al. (2007) reported similar energetic efficiency for CAN and NL calves, whereas CSN calves were less energetically efficient. That study revealed less fat deposition in EBW for CSN than CAN, and intermediate fat deposition for NL calves. However, a difference in EBW composition at weaning was not detected in this study. Several studies have shown that different types of crossbreeding change feed intake and energy deposition differently (Frisch and Vercoe, 1969; Ferrell and Jenkins, 1995; Almeida et al., 2005). The

Table 3. Sex comparison (least squares means ± SE) for preweaning performance, body composition at weaning (190 ± 11 d), and efficiency of straightbred Nellore, F_1, and 3-breed cross calves

	Calf sex		
Variable	Male	Female	P-value
Birth wt, kg	37.2 ± 1.3	36.7 ± 1.6	0.82
Weaning wt, kg (190 d)	207 ± 5.4	199 ± 6.4	0.35
BW gain, g/d	888 ± 2.6	849 ± 3.1	0.42
Empty BW (EBW), kg	186 ± 5.2	176 ± 6.1	0.21
HCW, kg	115 ± 3.2	109 ± 3.8	0.21
Liver, kg	2.22 ± 0.06	2.03 ± 0.07	0.05
Kidney, kg	0.48 ± 0.02	0.41 ± 0.02	0.01
Kidney-pelvic fat, kg	3.74 ± 0.48	5.22 ± 0.56	0.05
Liver, % of HCW	1.94 ± 0.04	1.87 ± 0.05	0.22
Kidney, % of HCW	0.42 ± 0.01	0.38 ± 0.02	0.08
Kidney-pelvic fat, % of HCW	3.22 ± 0.4	4.65 ± 0.4	0.02
Water, % of EBW	64.2 ± 0.4	62.5 ± 0.4	<0.01
Chemical fat, % of EBW	13.2 ± 0.5	15.2 ± 0.5	<0.01
Protein, % of EBW	18.1 ± 0.06	17.8 ± 0.07	0.03
Ash, % of EBW	4.52 ± 0.02	4.45 ± 0.02	0.03
Gross efficiency,[1] g/Mcal	155 ± 5.6	151 ± 6.5	0.66
Energetic efficiency,[2] kcal/Mcal	339 ± 14	355 ± 17	0.46

[1]Grams of BW gain/Mcal of ME intake (milk plus silage).
[2]Kilocalories of retained energy/Mcal of ME intake (milk plus silage).

benefits of *B. taurus* × *B. indicus* crosses from heterosis and complementarity effects were detected in all preweaning performance traits. However, the reduced requirements of NL calves allowed the straightbred group to show the same efficiency of crossbreds.

Implications

Crossbred calves from straightbred cows (ANL) ate more (18.5%), grew faster (29.9%), weighed more at weaning (21.5%), and had heavier EBW (22.5%) and HCW (23.7%). Further improvement in productivity was observed with the Canchim-sired calves from crossbred cows (CAN and CSN). Those calves ate more (32.9%), grew faster (40.7%), and had heavier weaning (33.7%), EBW (37.1%), and HCW (37.6%) than straightbred NL calves. Calf preweaning gross (9.8%) and energetic (9.0%) efficiencies of those systems were numerically, but not statistically, improved as compared with the straightbred system. These results demonstrate the benefits of crossbreeding systems for improved the productivity for commercial beef production. Improved productivity without a reduction in biological efficiency is expected to be economically advantageous in most situations. Further, research on postweaning growth, carcass and meat characteristics, reproduction efficiency, and maternal ability need to be considered.

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